Beamline 9.3.1: Monochromator Upgrade

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INTRODUCTION

A double-crystal monochromator is installed on bend-magnet beamline 9.3.1. It is designed to provide photons in the energy range 2.3 to 5.5 keV. Although it has successfully operated for energy scans over limited energy ranges, it has generally not been used for applications requiring scans over a large energy range, e.g., for EXAFS. The monochromator has been redesigned and rebuilt for improved performance. The upgraded monochromator shows improved thermal and mechanical stability, and energy scans over large energy ranges are now possible. A new control system and user interface are being implemented. The beamline is now ready for users.

ISSUES

The performance of the monochromator as designed was limited by several factors.

- thermal stability due to insufficient cooling of the first crystal;
- mechanical stability of the crystal mounts;
- lack of position readouts of crystal adjustments;
- outdated and undocumented control system.

The primary limitation of the monochromator is that the first crystal absorbs significant heat, resulting in thermal expansion and an increase of d-spacing of the crystal. This effect, before cooling was implemented, was time and photon-energy dependent, and limited both scanning range and stability of beam position and intensity with time. A second limitation was mechanical stability of the crystal mounts, and coupling of crystal motions (theta and chi angles). Picomotors were used to control theta and chi adjustments inside the vacuum, but, without position readouts, it was easy to get lost, resulting in tuning difficulties and unforgiving operation. Finally, the control system was essentially non-commercial and undocumented, and the LabView code was not documented, resulting of difficulties in upgrading the equipment and/or the operating system.

IMPROVEMENTS

The ground rule for upgrading the monochromator was to preserve the mechanical linkage (the “boomerang”) which controls the position and angle of the two crystals in the monochromator.

The crystal mounts were totally re-engineered. The primary improvement was to add water cooling to the first crystal. This was achieved by circulating chilled temperature-controlled water through a copper plate which is part of the mount for the first crystal. Indium foil and a gallium eutectic are the heat-transfer media to cool the first crystal.

The support arrangement for each rotation axis of the crystal mounts was changed from a single flexural hinge to a pair of flexural hinges, providing considerably improved mechanical stability and isolation of theta and chi motions.

Theta and chi coarse adjustments are made, as before, by picomotors in vacuum. However, a piezo actuator has been added in series with the picomotor for adjustment of theta (theta puts the second crystal on the Bragg peak of the first crystal) for eventual feedback on either photon beam intensity or vertical beam position (which are coupled). Provision has been made for installing a piezo actuator for adjustment of chi (left-right tilt adjustment of the second crystal) should fine adjustment and/or feedback on horizontal beam position be required.

LVDTs (Linear Variable Differential Transformers) were installed to measure theta and chi position. These allow computer control of theta and chi, feedback, and maintaining reference positions. The beamline is now easy to tune and control.

The LabView code running the control and data-acquisition systems has been entirely rewritten, keeping the flavor of the previous code while adding new features, making operation of the beamline more user friendly, and having a maintainable code. New counting cards add additional counting channels.

Many improvements were made to mechanical parts of the boomerang and crystal mounts, primarily in the selection of materials to provide smooth long-term operation and to minimize galling and other maintenance issues. The rotary parts of the mechanisms were redesigned and rebuilt as needed.

OPERATION and TESTING

Energy repeatability is of concern to users when multiple scans are made over the same energy range. The method used previously was to remove backlash from the mechanism by selecting a low energy, then increasing the energy to the starting point of the scan. Motor steps were counted to determine energy. A tilt sensor was used to “home” the motor from time to time. We found that motor steps are not a reliable method for determining photon energy. For example, a series of measurements of photoabsorption in argon gas had the peak spread over greater than 1 eV, with a mean spread of nearly 0.4 eV. The tilt sensor, previously used for homing only, was at least a factor of two better (see Fig. 1). We are thus using the tilt sensor to measure photon energy, pending installation of a rotary encoder for installation on the rotation axis of the first crystal. This will provide improved energy repeatability.

Tests are underway on beam size and beam-position stability. Initial results show a beam of less than 1-mm diameter, with beam position stability of +/- two mm in scans over a range of 2000 eV. Flux is relatively constant in scans over a large energy range (see Fig. 2).

Energy calibration has been accomplished using photoabsorption and photoemission measurements.

The new user interface is integrated with the new control system, and is presently undergoing testing. It is being phased in as new functions become available.

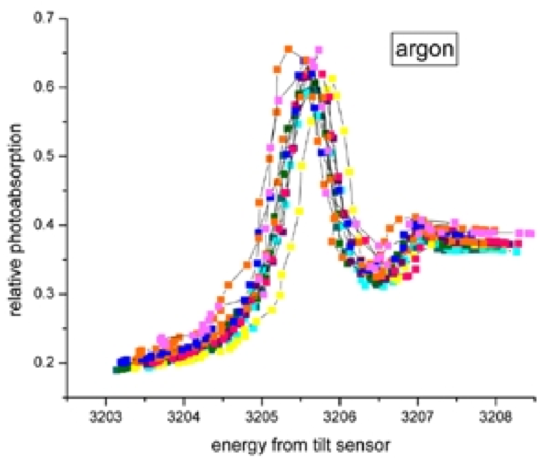

Figure 1. Relative photoabsorption in argon gas as a function of photon energy (eV) as measured by the tilt sensor. Multiple scans are shown to indicate repeatability.

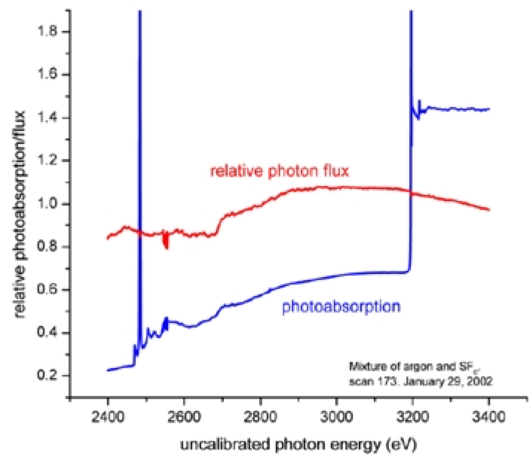

Figure 2. Relative photoabsorption and photon flux for a mixture of argon and SF_6 gases. Scan was made continuously with no adjustments.

OUTLOOK

We expect beamline 9.3.1 to operate with greatly improved stability and ease, and greater scanning range than was previously possible. It is a very useful beamline for K-shell studies on elements from sulfur through vanadium, and for L-shell and M-shell work on elements with electron binding energies in the range 2300 to 5500 eV.

ACKNOWLEDGMENTS

We thank Alastair MacDowell, Dennis Lindle, Will Thur, and Wayne Stolte for their kind assistance to this project.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Science Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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